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RADAR OBSERVATIONS OF VENUS IN THE SOVIET UNION IN 1964

by

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SUMMARY

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This paper describes the results of radar location of Venus during 1964 as the continuation of previous similar observations in 1961 and 1962. It is found that the energy of reflected signals decreases more rapidly with the increase of the incidence angle than was observed in 1962. A joint consideration of the results of determination of Venus' rotation period in 1962 and 1964 shows that the orientation of the rotation axis is nearly perpendicular relative to Venus' orbit plane.

author

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Radar observations of Venus were continued during 1964 by the Institute of Radio Engineering and Electronics jointly with a series of other organizations from 11 to 30 June. Measurements were conducted with the aid of the same installation as in 1961 [1] and 1962 [2] in 40 cm. A paramagnetic and parametric amplifiers were utilized at input. Signal analysis was made from a magnetic tape of a 20-channel analyzer. The filter bandwidth of each channel, converted to received signal, constituted 1.2 cps.

Two forms of modulation of the emitted signal were mainly used: a frequency manipulation and a periodical linear frequency modulation similarly to what was done in 1962 [2, 3].

* RADIOLOKATSIONNYYE NABLYUDENIYA VENERY V SOVETSKOM SOYUZE V 1964 G.

The emitted signal had at frequency keying the form of alternating telegraphic dispatches in two frequencies, differing either by 62.5 or 2000 cps. The duration of dispatches and pauses constitutes 4.096 seconds in each frequency. This form of modulation was applied for the study of the spectrum of reflected signals and for the measurement of radial velocities of Venus' motion, which was determined by the Doppler shift of the central frequency of signal's spectrum relative to the emission frequency.

The linear frequency modulation was applied for the study of the law of radiowave reflection from the surface and for the measurement of the distance to Venus. The frequency of emitted oscillations varied in a saw-toothed manner [3]; three regimes were then utilized: 4 kc/s deviation with a 1.024 sec.period (as in 1962), 32 kc deviation with period of 8.192 sec and a 32 kc deviation with a period of 1.024 sec. A deviation increase by a factor of 8 allowed to increase the precision of measurement of the distance and the resolving power for the study of the law of reflection from surface by the same factor. At reception the heterodyne frequency varied also according to saw-tooth law, but with a lag for the computed time of signal propagation to planet and return. If the computed lag corresponded exactly to the real time of signal propagation to planet and back, the signal frequency at received output was nominal. The correction to computed lag time was found by signal frequency deflection from nominal value.

The results of measurement of the distance to Venus and of radial velocity of its motion are plotted in Fig. 1. In Fig. 1 a we plotted the difference Δr (km) between measured and computed values of the distance from the point of measurement to the nearest point of Venus' surface; the distance Δv_r (cm/sec) between the measured and the calculated value of radial velocity of reflection center on Venus relative to the point of measurement is plotted in Fig. 1б. The root-mean square errors of measured values are shown by vertical segments.

When measuring the distance the root-mean square instrumental error for a single 5-minute session did not exceed 15 km to 23 June with 4 kc deviation and 2 km after 23 June (with 32 kc deviation; the error in the measurement of velocity did not exceed 2.5 cm/sec.

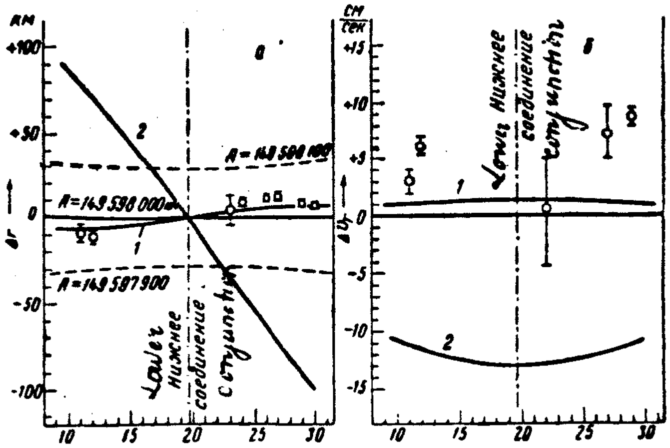

Fig. 1. - Measurement of the distance to Venus (a) and of radial velocity of its motion (δ) relative to the calculated value, June 1964

In the calculations of the time of signal propagation and Doppler frequency shift the following was assumed : astronomical unit — 149 598 000 km, speed of light — 299 792.5 km/sec, radius of Venus — 6 100 km. The time of signal propagation was computed with a precision to ±5 sec, the Doppler frequency — to ± 0.05 cps. The calculation of planet's coordinates was made on the basis of the Newcomb analytical theory, taking into account the corrections for Venus' orbit elements according to "Dankom" * data and the corrections for orbit elements of the system Earth-Moon according to Morgan data. Moreover, the additional shift of Venus' center along its orbit in the direction of motion by 250 km was also taken into account in the calculations. The displacement was determined in 1962 [2] and was estimated to be 270 km, which is equivalent to the increase of Venus' heliocentrical longitude by + 0.52 sec. The smooth curves 1 of Figs. 1a and 1δ correspond to this shift. If the introduced correction for the shift were in reality absent, the experimental points ought to be laying on the plane curves 2. The dashed lines of Fig. 1a indicate how the quantity Δr would have to vary if the true value of the astronomical unit were equal to 149 598 100 and 149 597 900 km.

* in transliteration

According to these measurements the value of the astronomical unit is 149 598 000 km; at the same time if we take into account the possible systematic errors, the maximum error could be ±400 km.

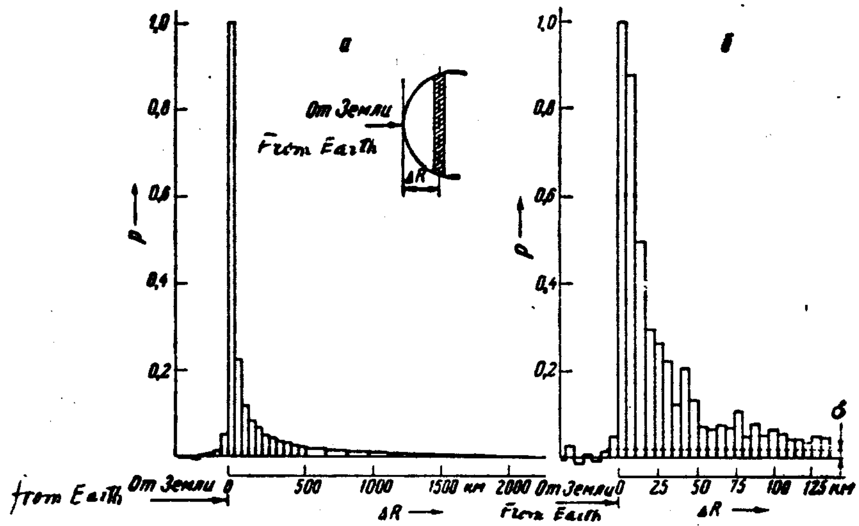

Fig. 2. Distribution by distance of the energy of reflected signals from Venus. - a - obtained at linear frequency modulation with 4 kc deviation ($\sigma = 0{,}0025$ for narrow filters and $\sigma = 0{,}0014$ for wide filters); б — obtained with 32 kc deviation.

The root-mean-square values of systematic errors in the initial data are estimated by the following quantities when converting to astronomical unit : speed of light 70 km; Venus' radius 40 km; heliocentrical coordinates of Venus and Earth 100 km; influence of the medium in which the signal propagates 10 km; determination of the lag in the apparatus 5 km. The total root-mean-square error is equal to 130 km.

The distribution of energy of Venus-reflected signals as a function of distance ΔR relative to the portion of surface nearest the Earth is plotted in Fig. 2. The distribution in Fig. 2a has been obtained after 27 sessions with linear frequency modulation at 4 kc deviation and period of 1.024 sec. The first 11 columns represent the energy of the signals reflected by annular zones of the surface of 45 km depth, the remaining — by depth of 150 km. The distribution in Fig. 2 б was obtained after 20 sessions at 32 kc deviation with 1.024 sec. period. Its application allowed a more detailed investigation of the law of reflection from the forward portion of surface and to obtain the energy from annular zones by 5.5 km in depth. The energy of the reflected signals P was found from these data as a function of the incidence angle φ (Fig. 3, curve 1). For comparison, the curve 2 indicates in the same drawing the analogous dependence obtained during the 1962 measurements.

Comparison of the results shows that in 1964 the energy of the reflected signals decreases more rapidly with the increase of the incidence angle φ than was observed in 1962. This, apparently, may be explained by the fact, that during the 1964 radar location Venus was turned at the Earth by its smoother side.

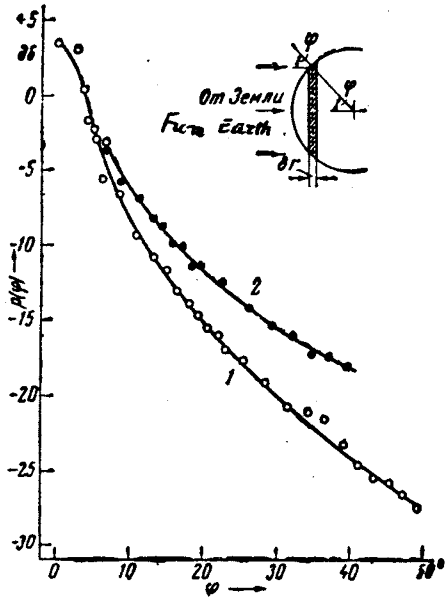

Fig. 3.- Dependence of the energy of reflected signals P on the angle of incidence φ.

The width of the Doppler spectrum of the reflected signal, conditioned by Venus' rotation, does not exceed 15 cps. The reflection factor of Venus [3], measured according to the total energy of the reflected signal, is, as an average, equal to 19%. The energy in the central band of 1 cps is approximately twice smaller than the energy of the whole spectrum.

Spectra of separate days of observations were utilized for the determination of the rotation period of Venus. To that effect they were compared with the calculated spectra for various rotation periods from the law of energy distribution represented in Fig. 2. The results obtained in 1964 are not in contradiction with the retrograde rotation of Venus with a period od 200 – 300 days, arrived at from radar observations of Venus, conducted in 1962 [2]. - The experimental results of 1962 [3] (a) and 1964 (b) are shown in Fig. 4. All these results agree well and correspond best of all to retrograde rotation of Venus with a period of 230 ± 25 days.

The joint consideration of the results of determination of the rotation period in 1962 and 1964 shows, that the orientation of the rotation axis of Venus is near to the perpendicular relative to its orbit plane.

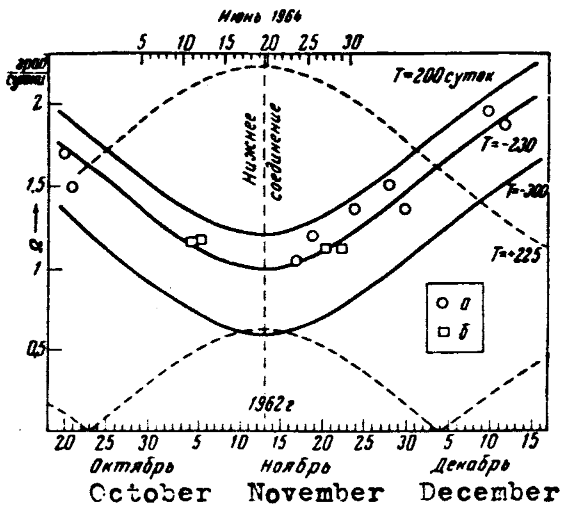

Fig. 4. - Determination of the period of Venus' rotation according to the rerult of radar location in 1962 (a) and 1964 (b). Ω is the angular velocity of Venus' rotation relative to locator. The dashed lines indicate the computed values of Ω for a direct rotation of Venus and the solid lines — for the retrograde rotation.

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**** THE END ****

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